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Some contributions of small mammal bio-climate studies to Air Force needs in northern regions.

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TECHNICAL NOTE

AAL-TN-56-8

# SOME CONTRIBUTIONS OF SMALL MAMMAL BIOCLIMATE STUDIES TO AIR FORCE NEEDS IN NORTHERN REGIONS

# SOME CONTRIBUTIONS OF SMALL MAMMAL BIOCLIMATE STUDIES TO AIR FORCE NEEDS IN NORTHERN REGIONS

By

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One of the basic tenets of biology is that an organism cannot be considered apart from its environment. In some regions of the world, man's edificarian* environment closely approximates local natural conditions which are suitable for primates. In the north country, however, the naked primate, man, must invest himself with an artificial tropical bioclimate in order to live successfully. If for any reason he is divested of portions of this artificial environment, whether because of an aircraft accident, fire, or military maneuvers, he is then thrust into the natural environment. Therefore, it behooves us to learn the extremes and means of the natural environment and especially to learn which aspects of the natural environment most closely approximate man's minimum needs.

Because the subarctic spruce forest or taiga covers such a vast portion of the land area of the world and because it is situated so as to act as either a barrier or a path between major human population centers, an analysis of the taiga environment is now necessary as a base for future scientific investigations and their application to practical human needs.

As far as the North American taiga is concerned the biological literature contains statements and concepts which indicate that there is a great lack of understanding and appreciation of the taiga environ-

*Definition of terms of a purely biological or ecological nature will be found in the appended glossary.

ment. For many years, even since its inception as a separate discipline, the focus of ecological attention in North America has been on the temperate portions, to the neglect of the Arctic tundra and subarctic taiga. A great deal of work has been done in the alpine tundra and montane coniferous forests which are easily accessible from the temperate regions, but just how much of this information may be extrapolated to the true tundra and taiga is a matter for speculation. Thus, it is evident that the work which is most needed in the North American taiga is basic natural history in order to establish a firm foundation for more specialized and restricted investigations.

Another basic concept of biology is that organisms are not distributed at random, but exhibit various degrees of clumping or aggregation. According to the modern concept of ecology, these aggregations, in the case of small mammals, occur in the optimum habitats. Separating these islands of optimum habitat are areas of marginal or submarginal habitat. These areas of marginal habitat are occupied by any given species only when the combination of favorable environmental conditions and a sufficiently high population allows excess individuals from the population islands or reservoirs to spill over into the adjoining sparsely inhabitated submarginal habitat. Since there are relatively few mammal species adapted to taiga and tundra, and since the physical environment plays an increasingly important role in governing distribution and population state (Hesse, Allee and Schmidt, 1951), the relative importance of the bioclimate becomes greater as one moves poleward.

Thus, it is evident that in order to understand the factors influencing the local distribution of small mammals in the north country, one

must consider population dynamics and bioclimate as being intimately related. This we are attempting to do.

In the summer of 1954, Pruitt began an investigation of the factors influencing the distribution and population dynamics of small mammals in Alaska. From its inception, this investigation has been recognized as a long-term project, since year-to-year climatic variations as well as seasonal cycles must be reckoned with in order to gain an insight into the nature of the factors which go to make up the ecology of small mammals. Two major influences govern the minimum length of time that a study such as this should continue. These are (1) the frequency of the multiannual population cycles of the mammals concerned and (2) the length of time necessary to run the gamut of yearly climatic variations - from a "hard" year to a "good" year - since Andrewartha and Birch (1954) have shown that local distribution and population state are interdependent variables.

In order to test several hypotheses related to this problem, a series of study areas were established in the summer of 1954. These are named and situated as follows (Map 1):

SPR - An area of mature lowland subarctic spruce forest near Fairbanks.

GUL - An area of open subalpine spruce forest about ½ mi E. of Paxson Lake.

SUM - An area of Arctic-Alpine tundra about 1 mile S. of Summit Lake.

BPD - An area of dry, upland tussock tundra near the head of Sadie Creek (Kilivik) on the Baldwin Peninsula.

BPW - An area of moist coastal tundra at the mouth of Sadie Creek.

NEC - An area of moist coastal tundra at Northeast Cape, St. Lawrence Island.

MDR - An area of wet, polygonal tundra 46 miles S. of Barrow.

OJL - An area of scattered spruce "forest-tundra" near the SE shore of Old John Lake.

PPL - An area of spruce-birch-alder hillside near Fairbanks.

Most of these study plots, because of the difficulties of transportation, are used mainly in the population dynamics phase of the study, but three, (SPR, GUL, and SUM) because of their proximity to the laboratory or to the Paxson Lake Field Station are also used for microclimate study. Pruitt and Lucier handle the SPR area, while Hufman handles GUL and SUM areas.

This report is concerned with some of the aspects of the microclimatic analyses of these three areas. It should be thoroughly understood that the data presented here represent only two years work. They do not encompass the extremes of population state nor of secular climatic variations; therefore, any inferences which we may draw or which may be drawn from these data are subject to considerable revision as more data accumulate. Nevertheless, we feel that certain inferences are justified, particularly since they point the way toward a more efficient use of natural materials by the Air Force in its survival training program.

First let us examine the winter conditions of the macroclimate that prevail in the taiga of interior Alaska (Fig. 1). In October the temperatures start to fall steadily until the average by the end of November is about 0°F. The sky is usually clear. In December the

temperatures begin to level off below the 0 mark and the air becomes noticeably dry. Snow on the ground has seldom been more than two feet. December is the quietest month of the year since the wind averages only 3 mph from the north. January is the coldest month, with the average maximum below 0°F. Snowfall in January is usually heavier than in any other month. In 1937 there was more than 5 feet on the ground for a short time, but the average is around 2 feet. In February the ambient air temperature starts to climb. February precipitation is about half the January average. March precipitation is even less than February. The temperature trend is constantly upward and by the end of March the minimum temperature is usually above 0°F. In April the rapidly lengthening days keep temperatures climbing and by the end of April the ambient air is well above freezing. April is the driest month of the year.

Because of the almost complete lack of wind in the winter, snowfall accumulates on all non-vertical surfaces. This snow on the trees, known as kukhta to the Siberians or ah-pee in the language of the Kobuk Valley Eskimo, is very important to the ecology of mammals and birds, as Formosov (1946) has shown. We are at present analyzing the sequence of kukhta formation and fail to see if there is any relation to red squirrel activity.

The day-to-day progression of weather in the winter is almost entirely under the influence of air-mass movement, solar radiation being almost negligible during December and January.

From an inspection of Figs 1, 2 and 3 it is evident that the subnivean bioclimates of the small mammals which inhabit the taiga, subalpine forest and alpine tundra are quite different from the supra-

nivean bioclimates of the larger mammals.

In the subnivean environment of taiga small mammals the air is essentially saturated with moisture all the time that snow covers the forest floor. Light is, of course, almost non-available. The temperature of the soil, at the time of snowfall, is around 30-35°F. It falls very slowly, less than 1°F per week until the snow cover reaches about 20 cm. in depth. At this time it ceases to fall and usually rises to about +25 - +28F and then, as the snow cover increases, it may slowly rise to just below freezing. The temperature remains essentially stable until the ambient air goes above freezing during the day and the snow cover starts to compact, at which time it starts to climb. During the time of maximum degradation of the snow cover the thermal overturn takes place. When this happens the thermal gradient reverses itself so that the deeper soil is cooler than the surface.

The foregoing resume of winter bioclimatic conditions of taiga small mammals would hold true in a winter of "normal" snowfall. A snow cover that comes sooner and is thicker raises the soil temperature considerably and damps the temperature fluctuations, while a late or thin snow cover allows considerable drop in soil temperature and wider temperature fluctuations.

Scholander et al (1950a, 1950b, 1950c) have shown that the physiological critical temperature of taiga and tundra small mammals generally prohibits their use of the supranivean environment for more than a few moments. Thus, the major adaptation to the taiga which these animals exhibit is a behavioral adaptation to avoid the cold. This they do by taking advantage of the snow cover as an insulating blanket. Work by Johnson (1951, 1954) has confirmed the suitability of this

subnivean environment. The effectiveness of a full snow cover is seen by comparing the soil temperatures for the winter of 1954-55 with those for 1955-56 and by noting the increase in the snow cover during the latter year (Fig. 4). This has also been noted by Formosov (1946).

Of lesser importance than the snow cover, but still effective, is the deep and thick layer of moss which covers the floor of mature spruce stands. The effectiveness of the moss cover is demonstrated by the climographs (Fig. 5) which compare the climates at the surface of the moss cover with the base of it, 9 inches lower. The effectiveness of the snow is again demonstrated by comparing the climographs for the winter of 1954-55 with those for 1955-56. A wider and shorter climograph figure denotes a more stable climate than does a tall slim figure.

Johnson's work (1954) also demonstrated the importance of topographic irregularities in the formation of suitable microhabitats. From his work several points may be drawn that are of great potential value to the Air Force. Some of these are:

1. The sharp temperature gradient which exists immediately above a snow surface, particularly during periods of clear, calm and intensely cold weather (Fig. 6).

2. The temperature inversion which exists, during the deep cold, from 500 to 1,000 feet above the floors of the large valleys (Fig 7).

3. The fact that small depressions in the ground surface cause the formation of "cold pockets" by cold air drainage. The existance of "cold pockets" on a larger scale is well-known (i.e. - certain bowl-shaped valleys).

Hardy and Stoll (1954) have demonstrated the importance of radiant heat loss in the winter supranivean environment at Fairbanks. They found that the cold skies often resulted in "operative temperatures" 18 to 27°F below air temperature.

From the foregoing data and discussion it is evident that even during the periods of extreme low temperatures in the taiga of interior Alaska there exists beneath the snow cover a heat source of considerable magnitude and remarkable stability. There also exists a material in immense quantities and of excellent insulating properties - snow. There also exists the need for avoiding direct exposure to the full radiant heat loss load. Further work by this laboratory is in progress on practical applications of the principles elucidated above.

GLOSSARY

alpine - That part of a mountainous terrain between the timber-line and the zone of permanent snow or bare rock. Subalpine refers to the portion of a mountain below the alpine zone. Arctic - Alpine (capitalized) refers to the Marriam Life Zone which resembles true Arctic tundra in many respects but which may be found on sufficiently high mountains anywhere on the globe.

bioclimate - The conditions of temperature, moisture, air movement, light, etc. which immediately impinge on an organism.

biome - Climax plant and animal associations which have developed together through geological time and which are in harmony with the climate, together with the successional stages leading to the climax associations.

cycle - A phenomenon which occurs with predictable regularity. In this sense we refer to population densities which change from sparse to dense on a predictable schedule. This is in contrast to population fluctuations, which, in our present state of knowledge, are non-predictable.

ecology - The study of the relations of an organism with its environment.

edificarian - Term used to refer to man's structures and dwellings. Example: The house mouse lives in an edificarian environment, as opposed to the muskrat which lives in a natural environment.

environment - The complex of physical and biotic factors which affect an organism.

habitat - The place where an organism lives, or the place where one would go to find it.

microclimate - The environmental conditions obtaining in the region where turbulence caused by radiation reflection from the substrate affects them, as opposed to the macro-climate which is the zone above the effects of turbulence.

optimum - That portion of the range of variation of a factor or factors between the pessima which includes the conditions best suited for life for the organism concerned.

population dynamics - The study of the component parts of a population of organisms with the eventual aim of constructing a live-table for them.

subnivean - below the snow cover.

supranivean - above the snow cover.

taiga - Russian word for the circumboreal spruce forest, as opposed to tundra, a Russian word for the circumboreal treeless region generally north of the taiga.

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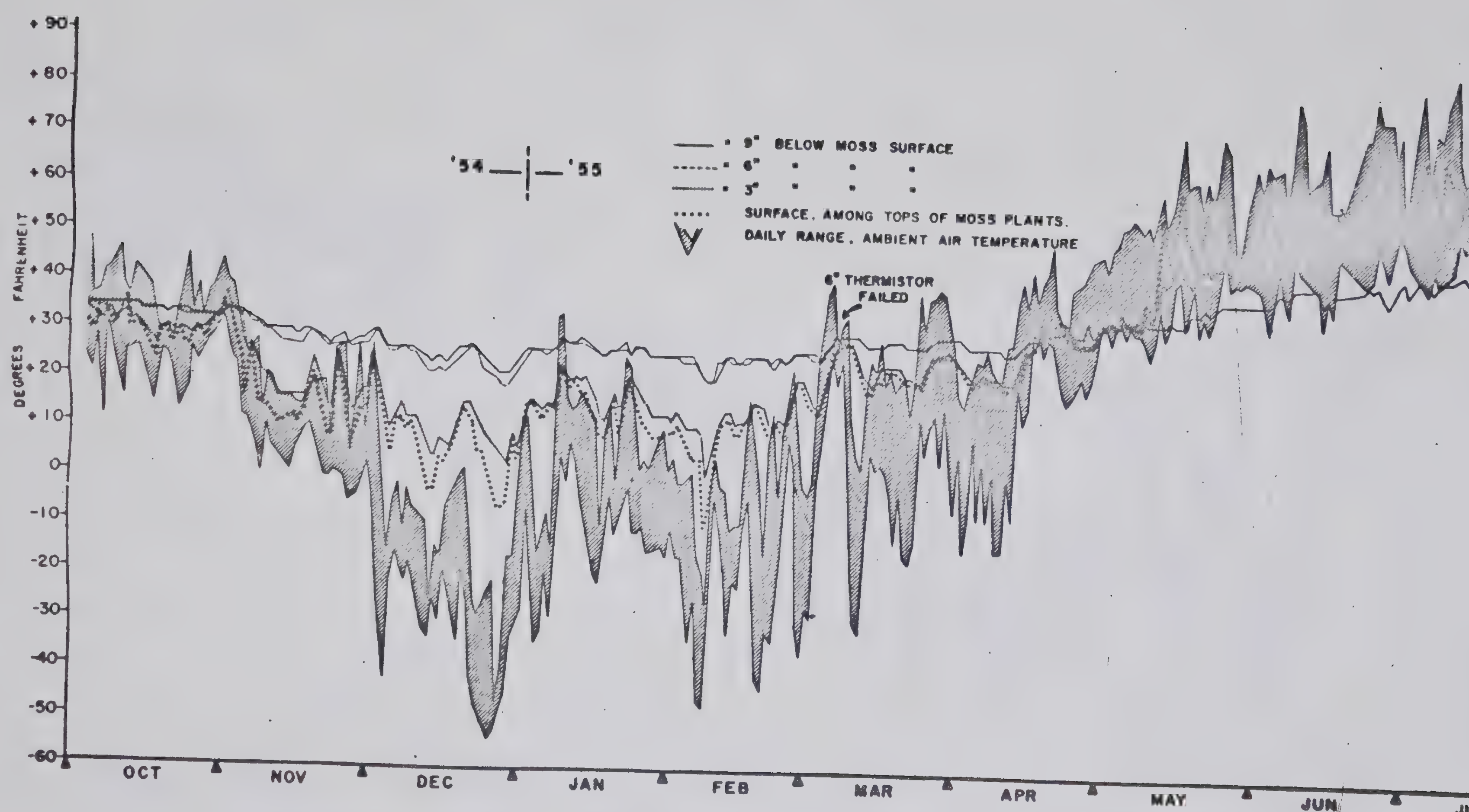



FIG. 1a-SUBARCTIC-SPRUCE, AIR AND SOIL TEMPERATURES, 1954-56.

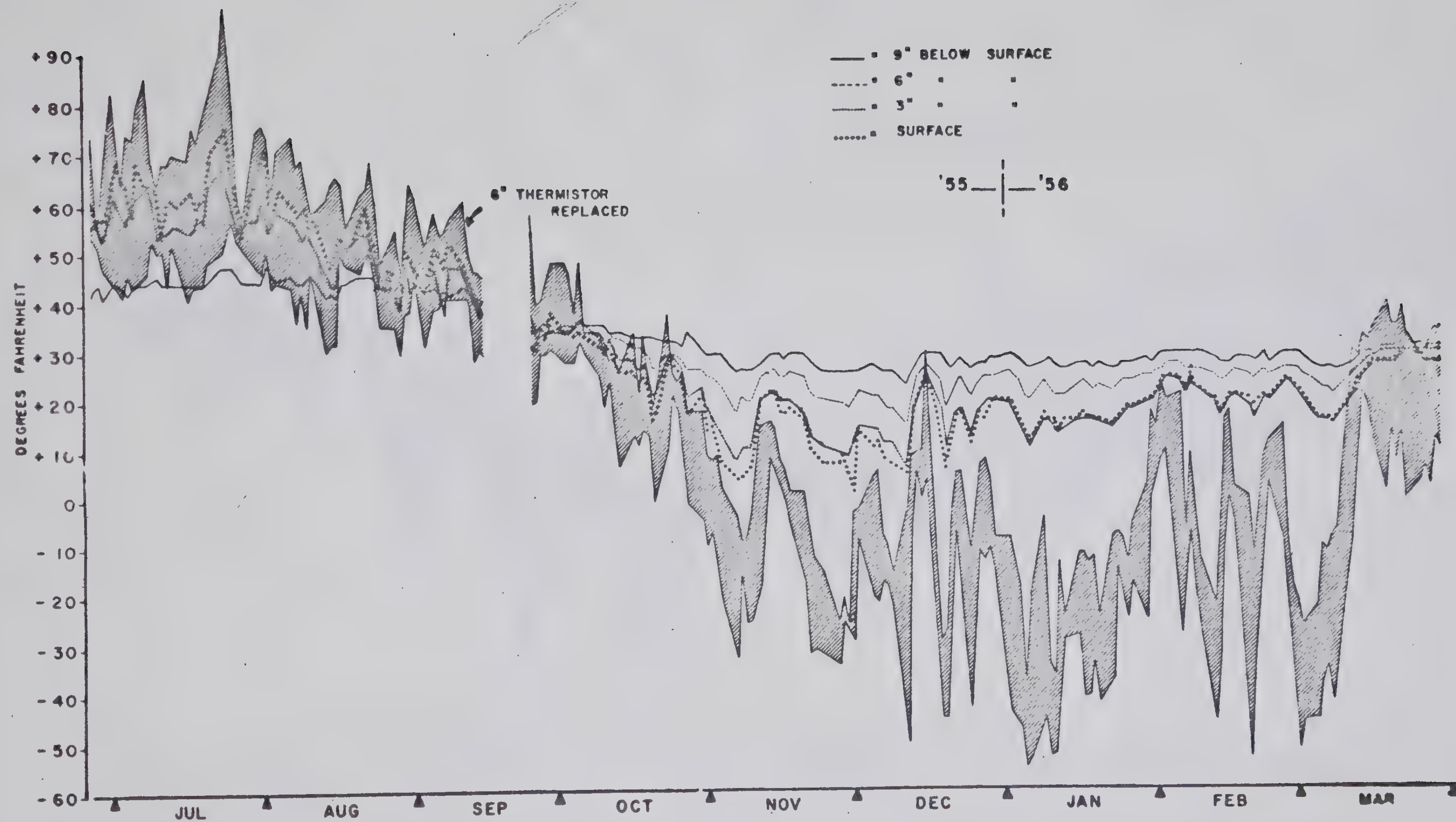



FIG. 16-SUBARCTIC-SPRUCE, AIR AND SOIL TEMPERATURES, 1954-56.

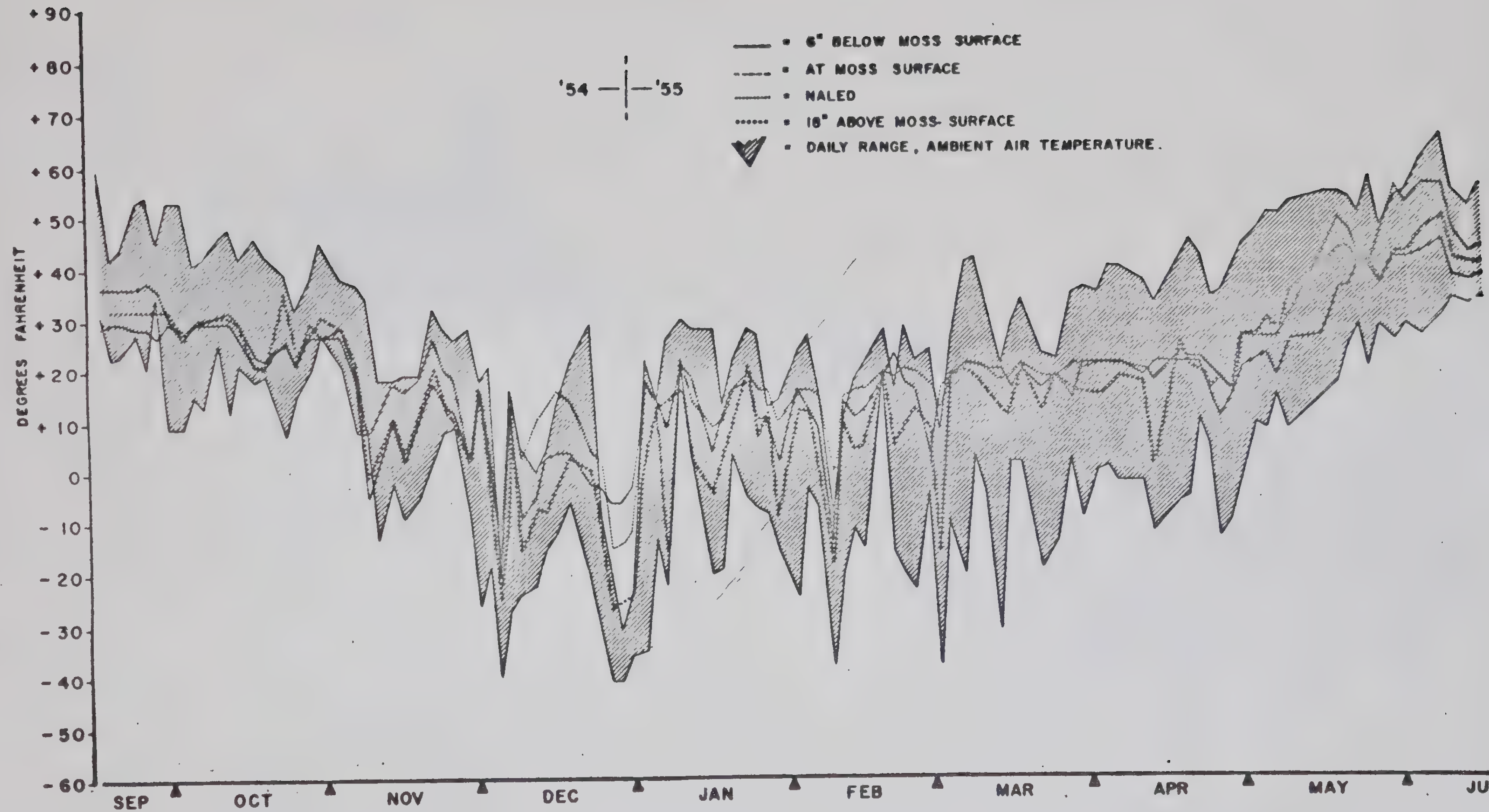



FIG. 2a-SUBALPINE-SPRUCE, AIR AND SOIL TEMPERATURES, 1954-56.

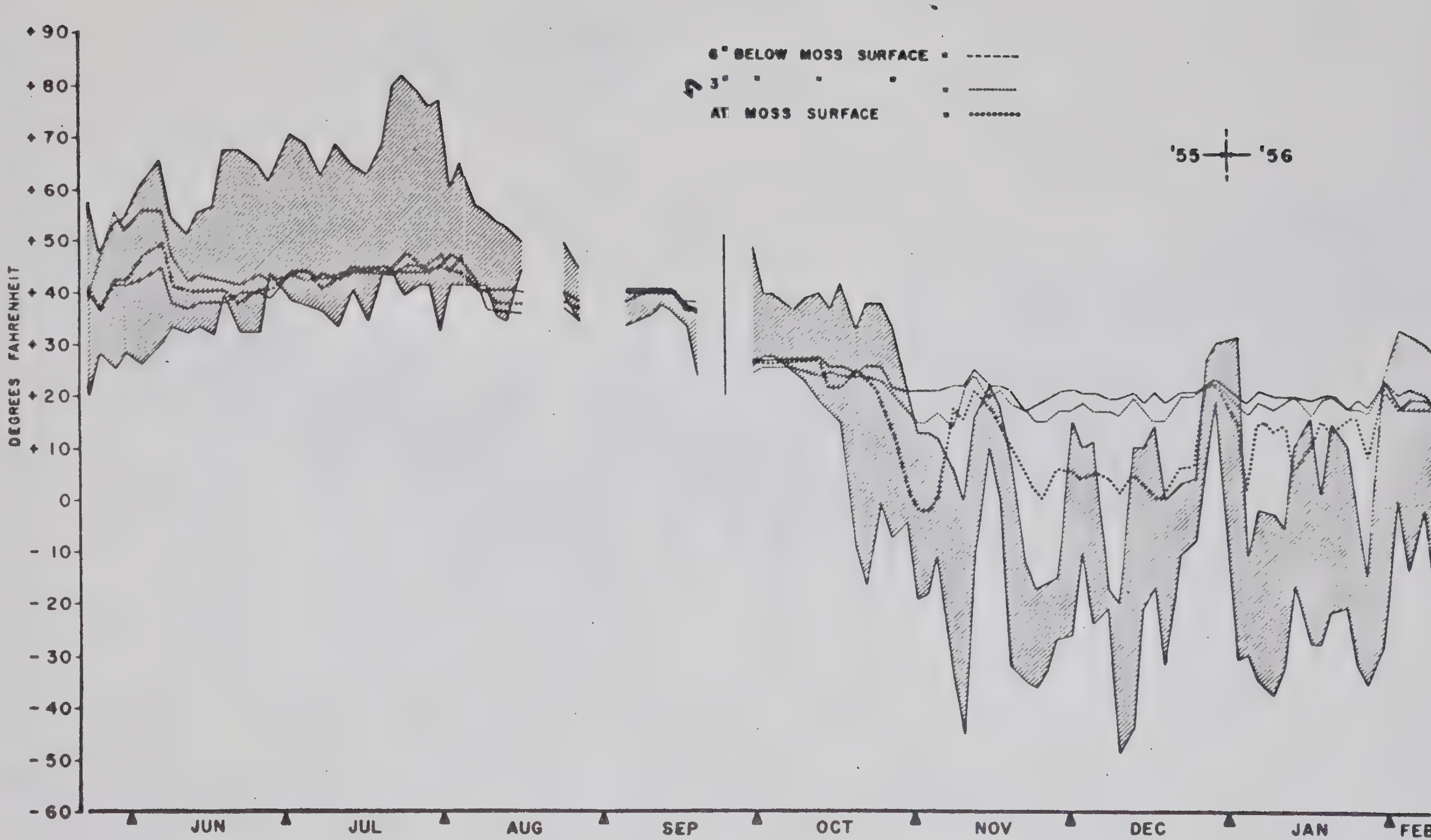



FIG. 2b-SUBALPINE-SPRUCE, AIR AND SOIL TEMPERATURES, 1954-56.

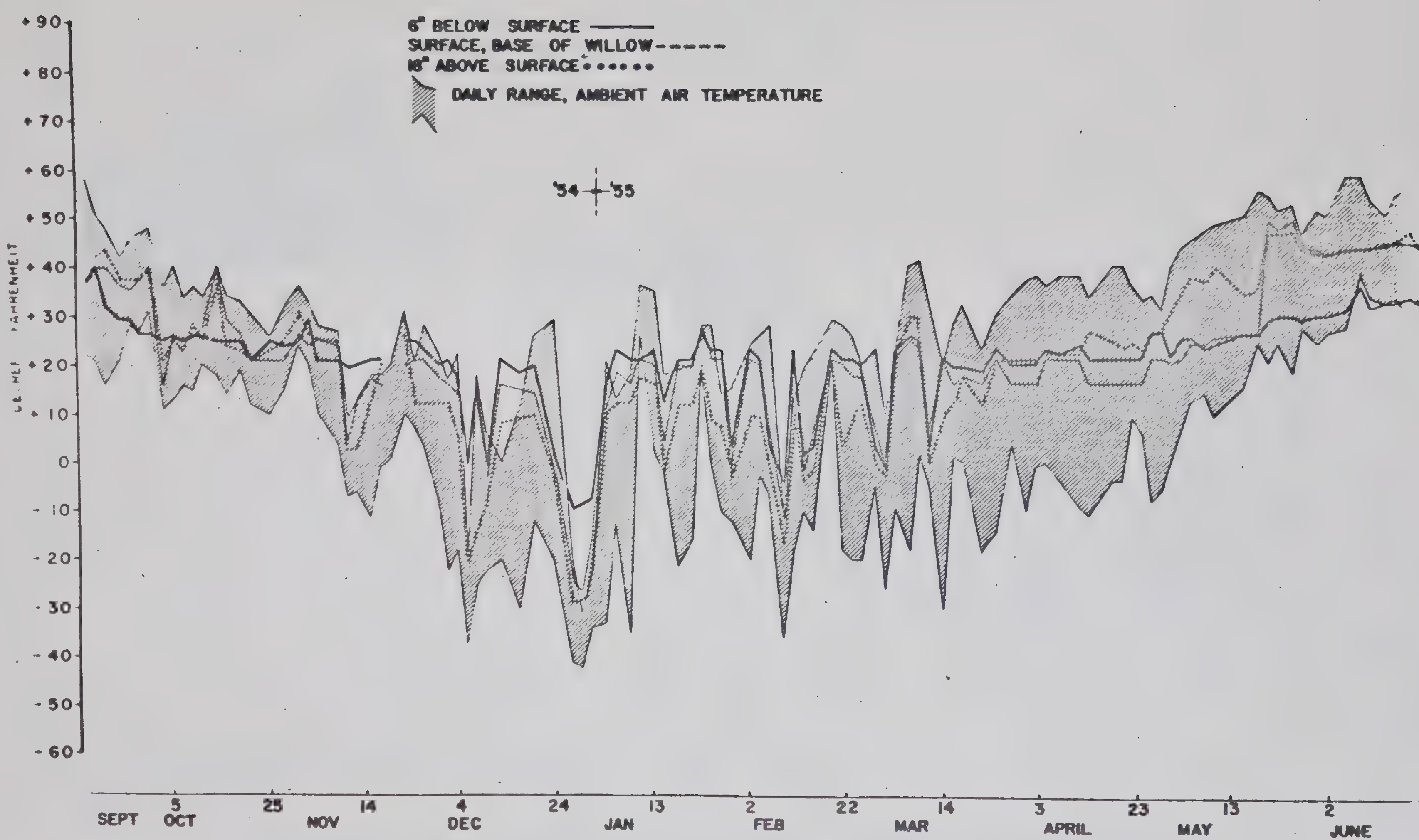



FIG. 3a-ARCTIC-ALPINE, AIR AND SOIL TEMPERATURES, 1954-'56

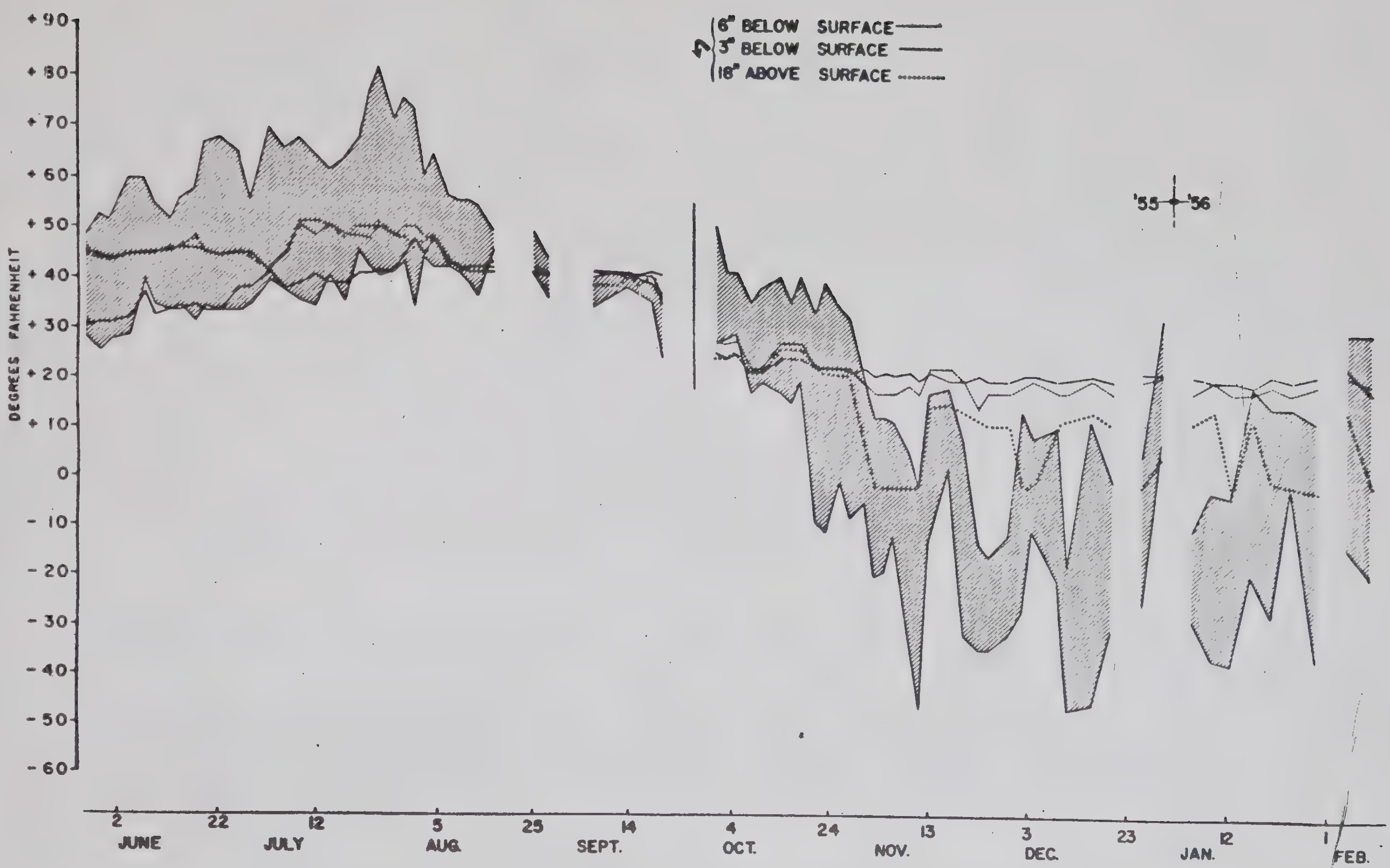



FIG. 36-ARCTIC-ALPINE, AIR AND SOIL TEMPERATURES, 1954-'56

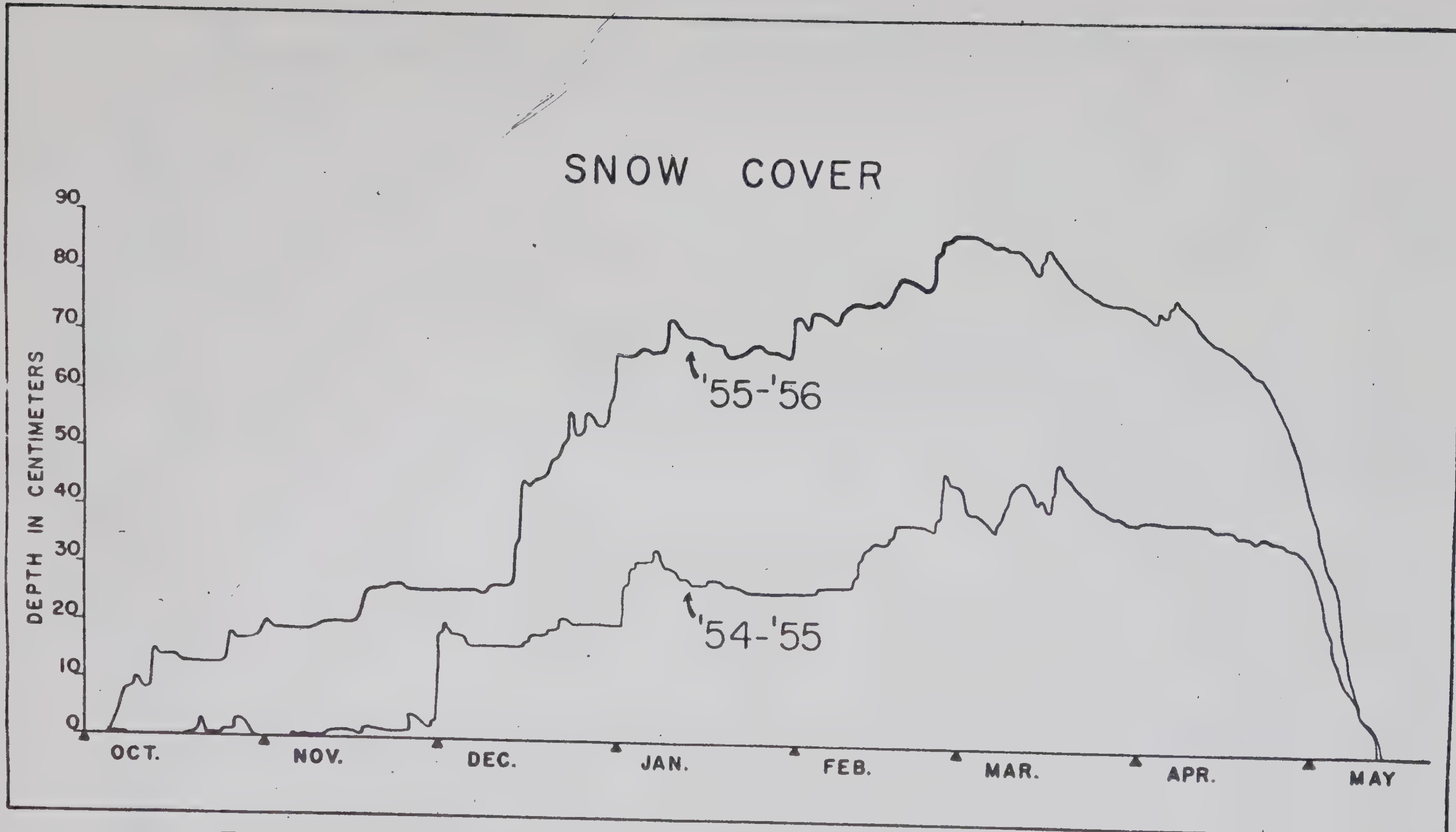



FIG. 4. SUBARCTIC-SPRUCE AREA · SNOW COVER

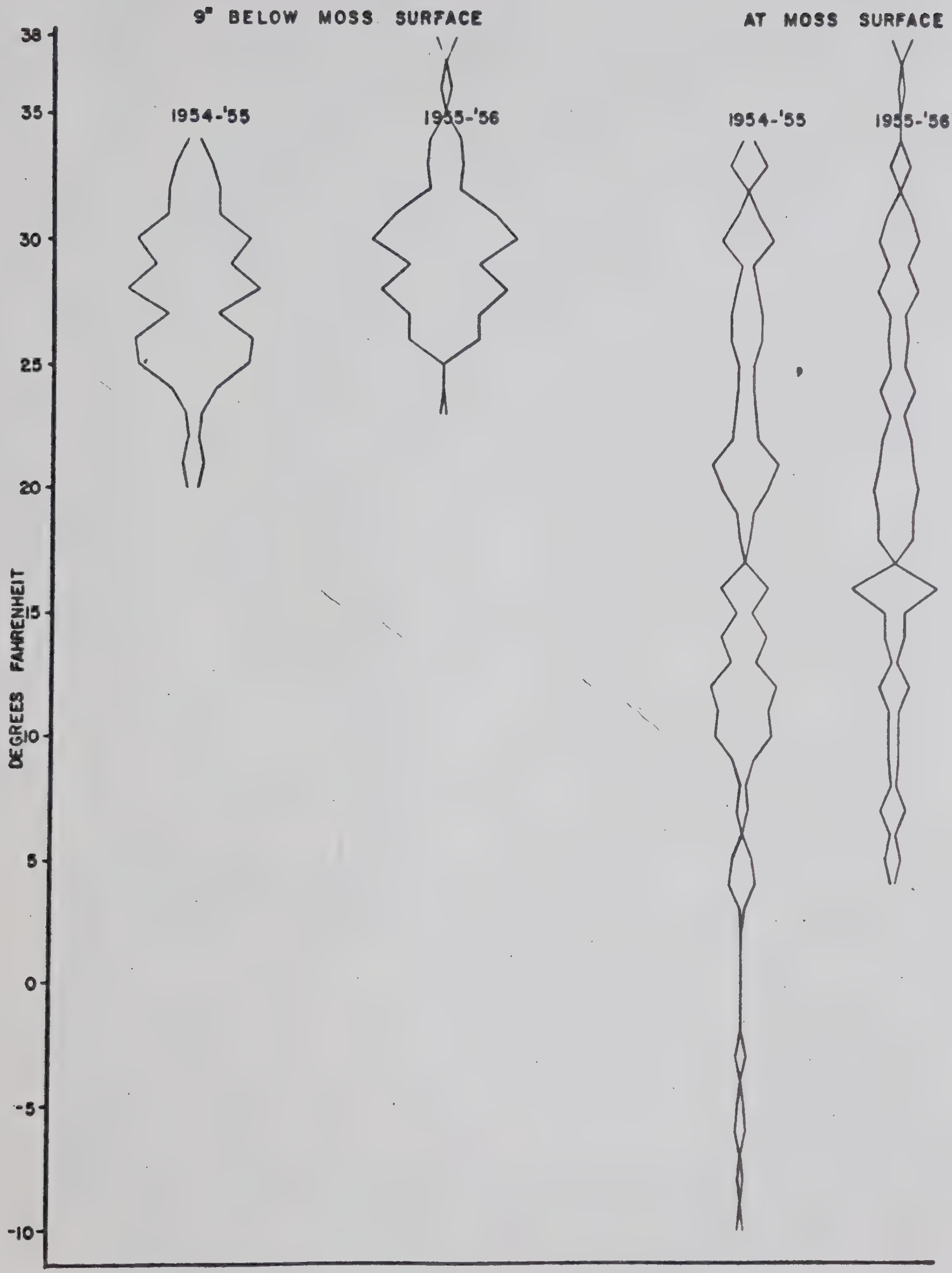



FIG. 5. CLIMOGRAPH, SUBARCTIC-SPRUCE AREA UNDER SNOW COVER

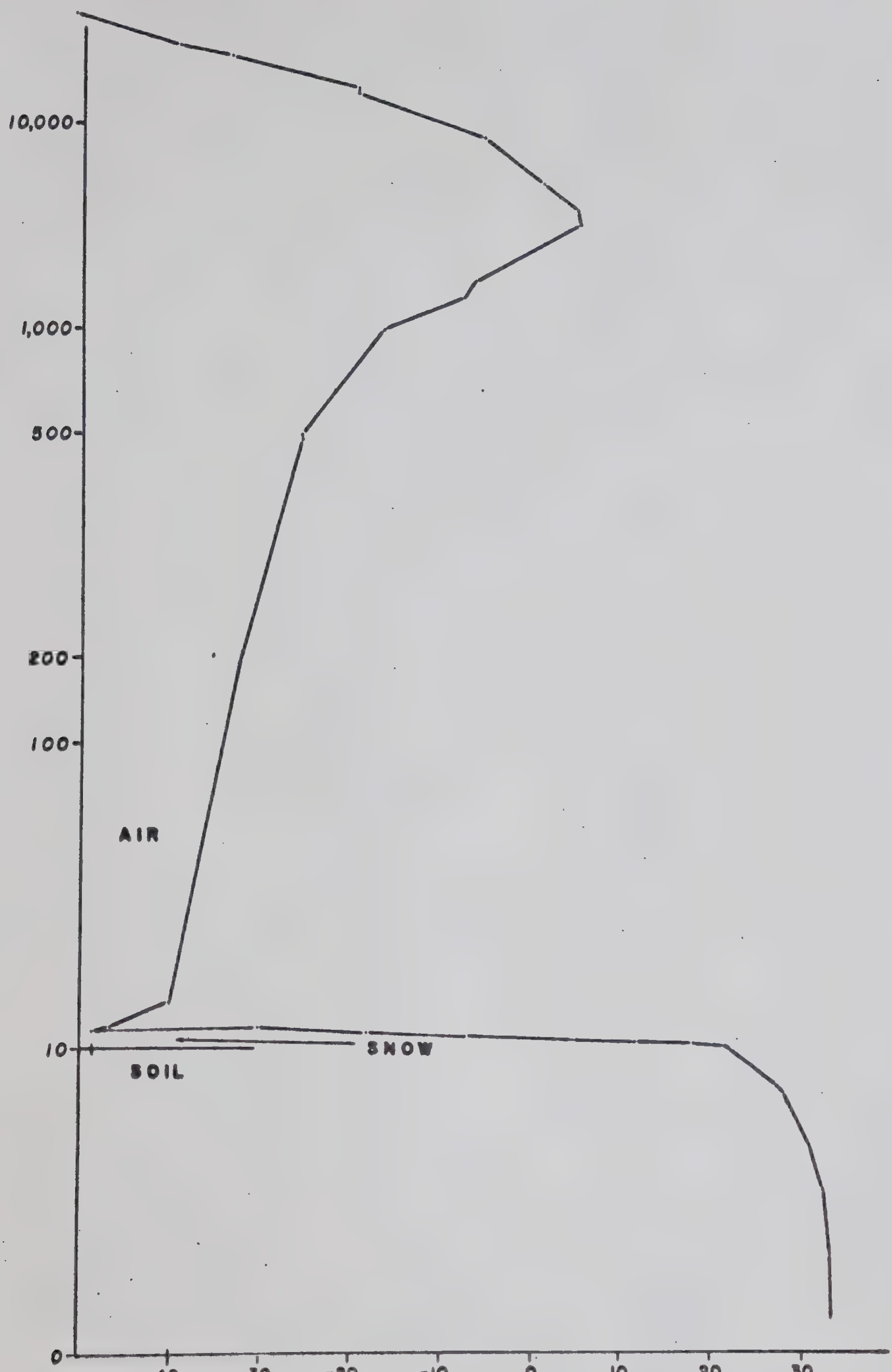



FIG. 6

TEMPERATURE GRADIENT, -10 ft. TO + 10,000 ft.

LOGARITHEMIC SCALE SO THAT DETAILS NEAR SOIL SURFACE ARE EMPHASIZED

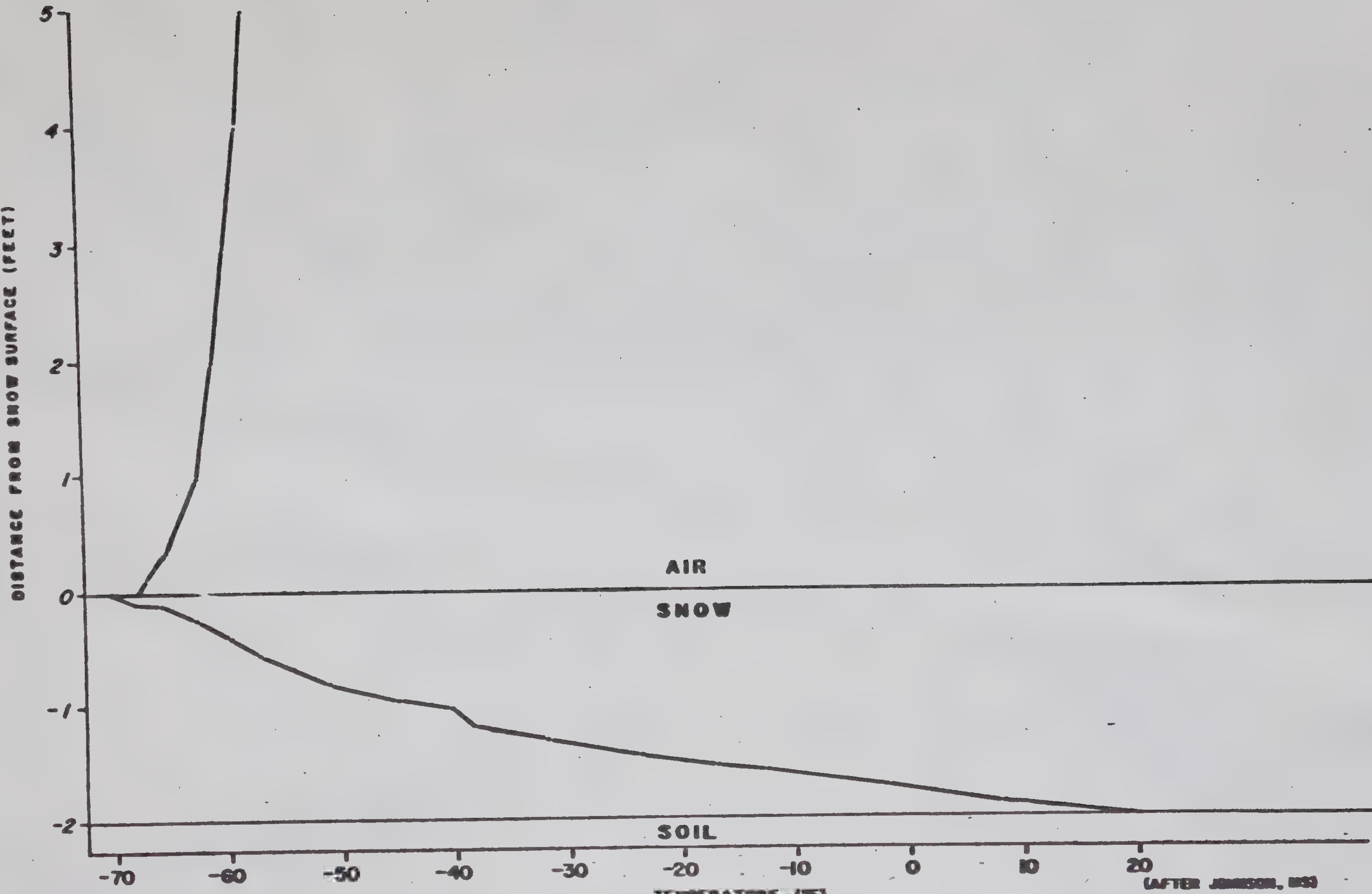
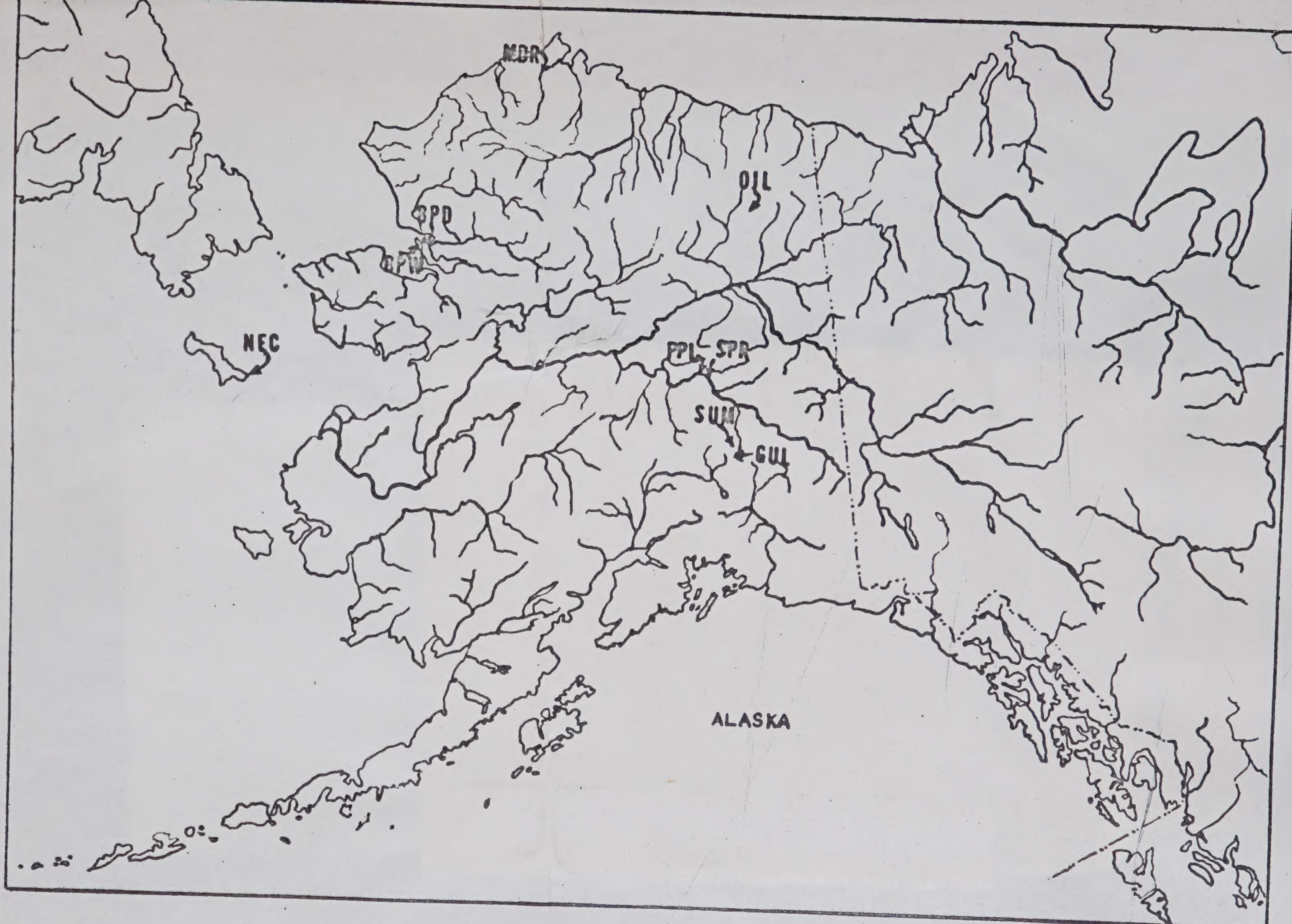



FIG. 7

TEMPERATURE GRADIENT NEAR SURFACE
SOIL SURFACE TO + 5 ft.




MAP I. LOCATION OF STUDY AREAS

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